Examples of slurry Retrieval, Pipeline Transport & Plugging and Mixing issues at Sellafield in the UK

Tim Tinsley & Dominic Rhodes
Nexia Solutions

nexiasolutions

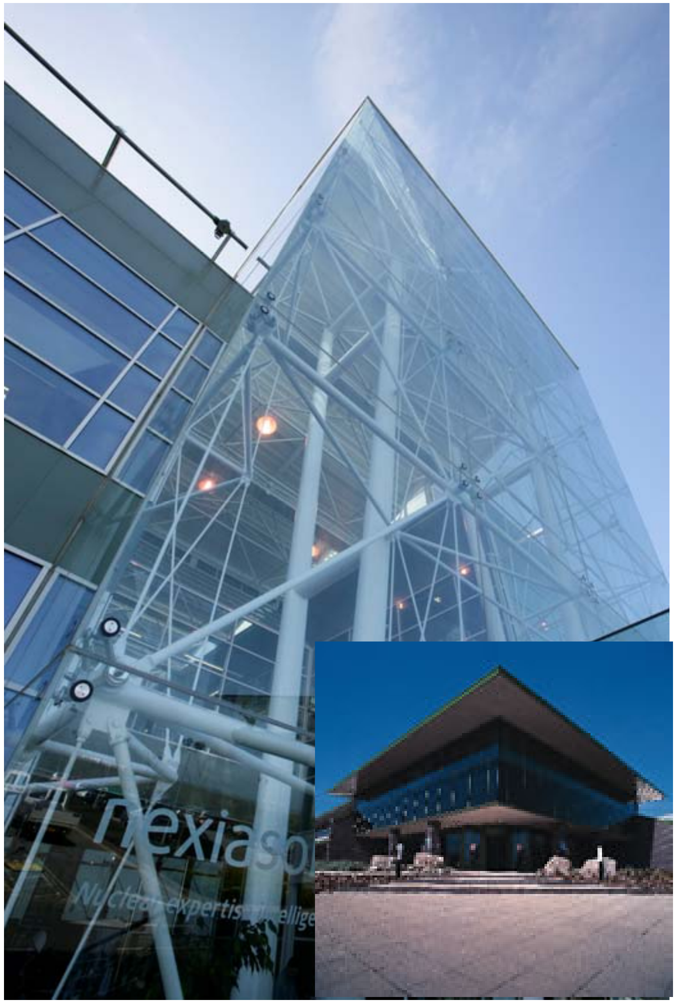
Nuclear expertise intelligently applied

Agenda

- Overview of Plant and Processes
- Examples of solid formation, and issues
- Examples of characterisation and management of solids

Nexia Solutions

- Pre 1996: Multi Centred Nuclear Technology Tradition
- 1996: Integrated R&T Function
- 2003: Nuclear Sciences and Technology Services (NSTS)
- 2003: Acquired AEA (T) Nuclear Science Business
- 2005: Nexia Solutions operate with full subsidiary Status
- **2008: National Nuclear Laboratory**



Remit for the UK's National Nuclear Laboratory

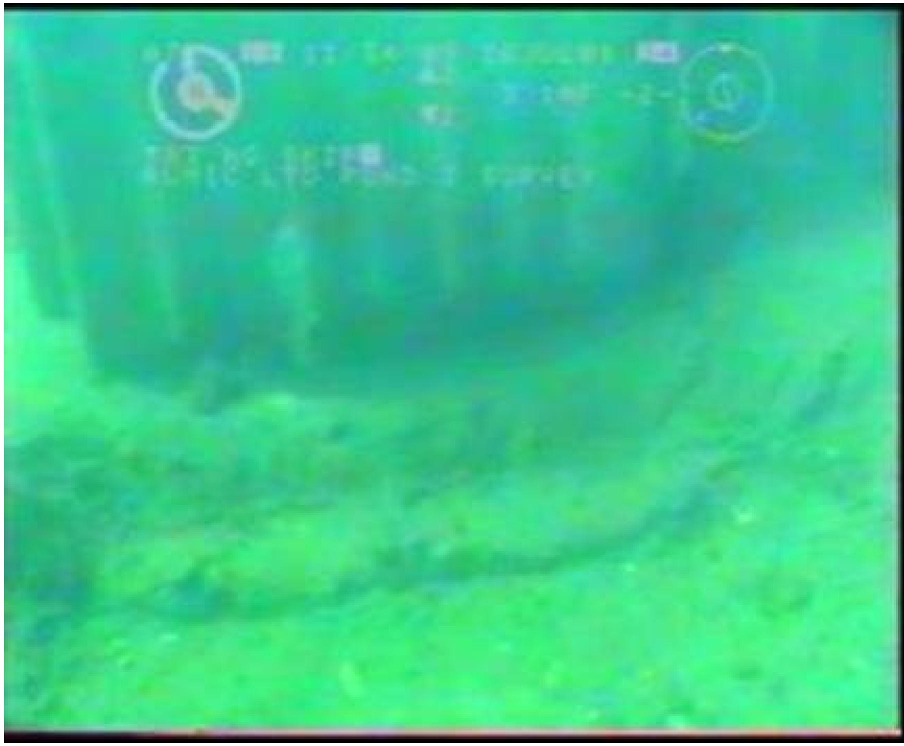
- Customer funded Laboratory with a key role to support the UK's strategic R&D requirements
- Development of the UK's R&D supply base
- Increased links to Universities
- Involvement in international programmes

The Sellafield Site

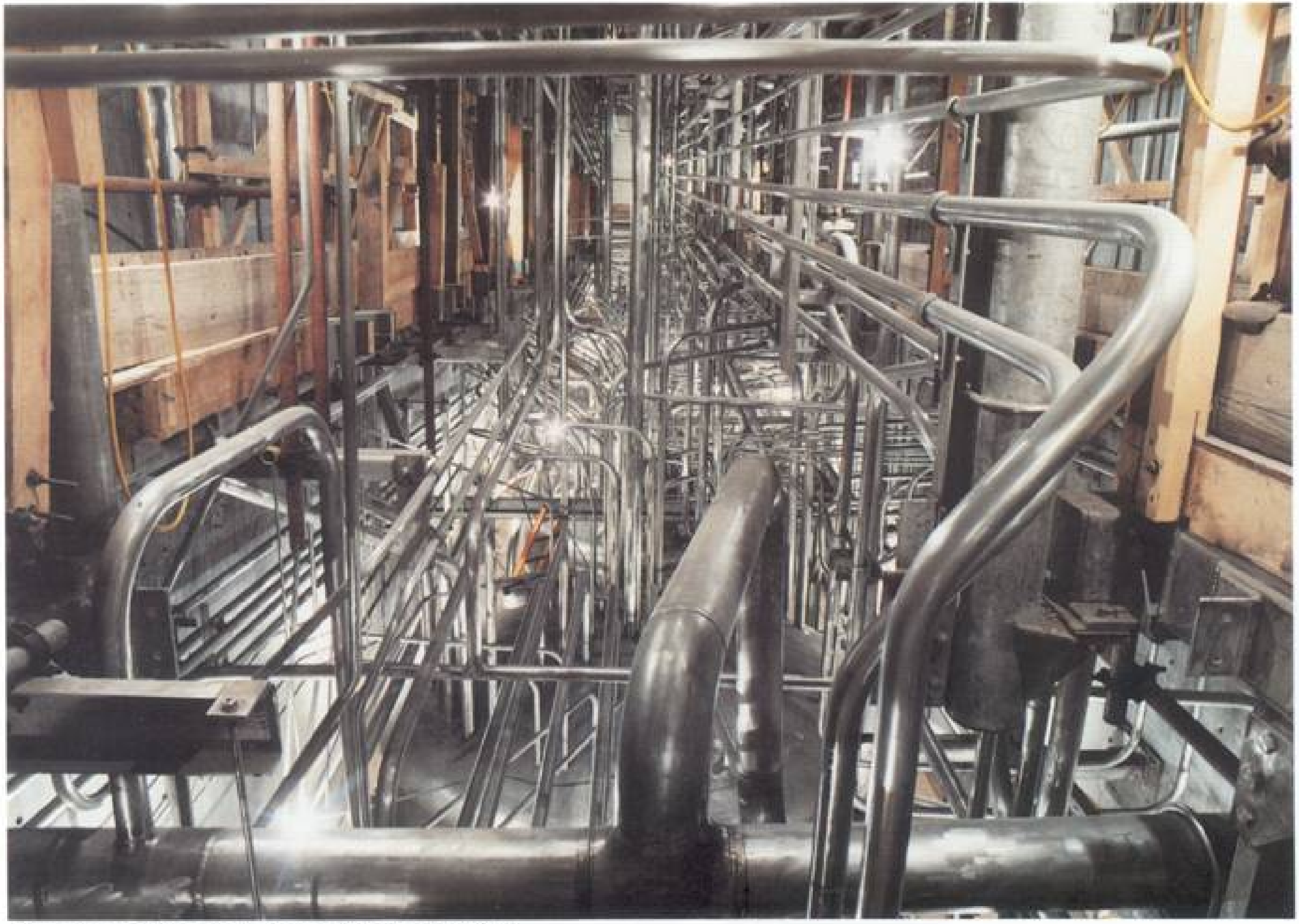
Plants & Process at Sellafield

- Variety of operational/legacy plants, ranging in age and hence engineering design
- Fuel storage Ponds, reprocessing plants, Supporting treatment plants, Interim storage plants, Product finishing plants
- Acid based solvent extraction
- Evaporation, storage and Vitrification
- Magnox corrosion product sludges
- Powder formation
- External conditions impose other constraints

Example of older Pond & Sludge

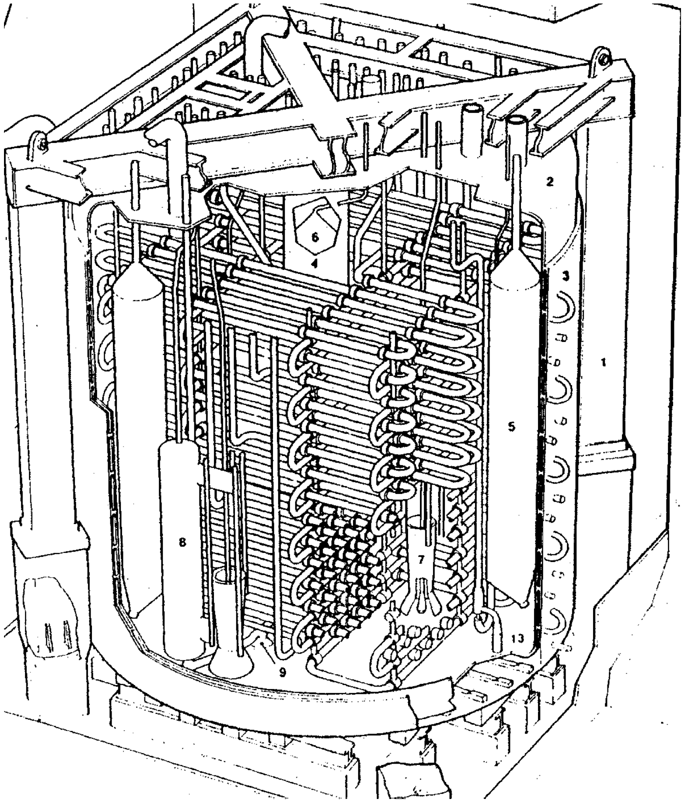


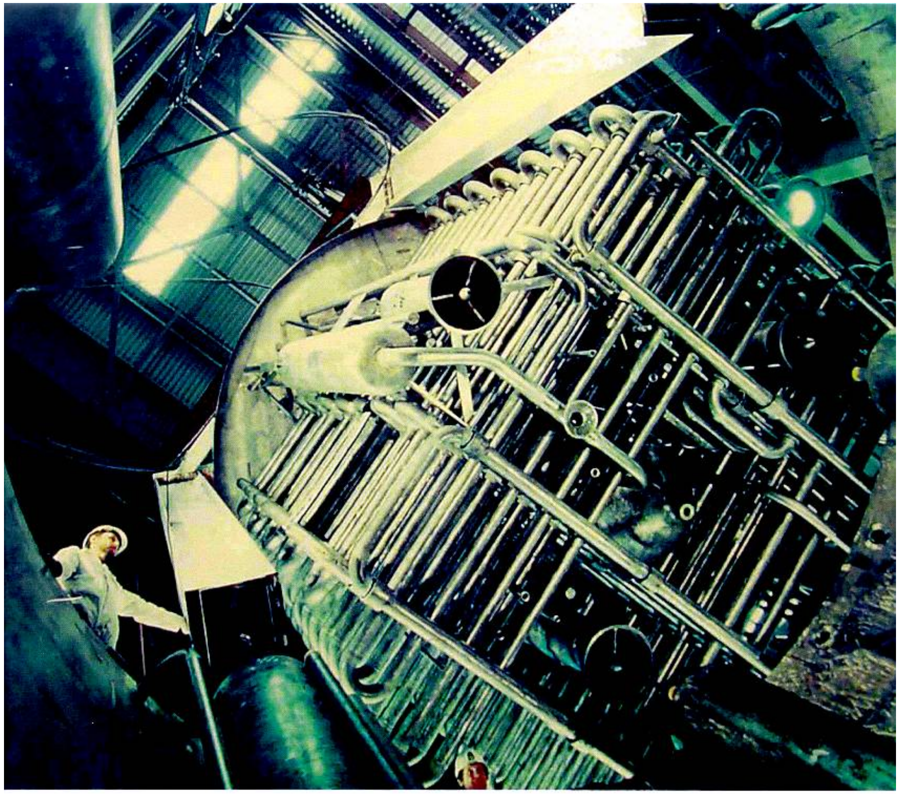
Example of complexity of pipework



Complex stainless steel pipework in the HAL Cell.

Example of complexity of pipework





Solid formation

- Solids can form due to a number of mechanisms
  - Precipitation - planned as product formation
  - Precipitation – consequence of concentration
  - Crystallisation – consequence of concentration, or result of change of condition
- Solids can be deposited due to a number of mechanisms
  - Cold surface crystallisation
  - Poor mixing or suspension
  - Settling during transport in pipes

‘Designed in’ problems

- Gravity fed part filled low slope pipes
- Changed in external conditions (temperature)
- Dilution (ejectors) & concentration (evaporation)
- Obstructions
- No access
- Non continuous mixing

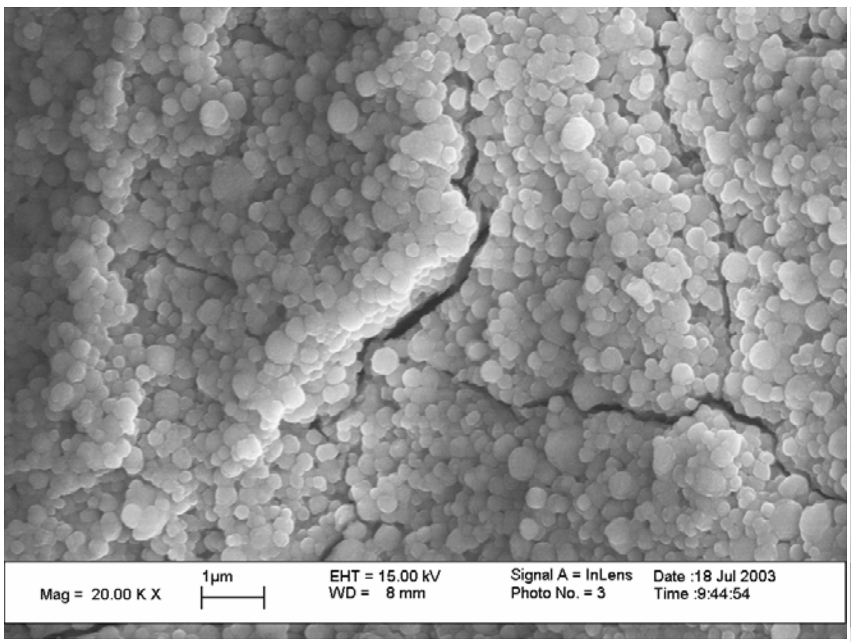
Highly Active Liquor chemistry

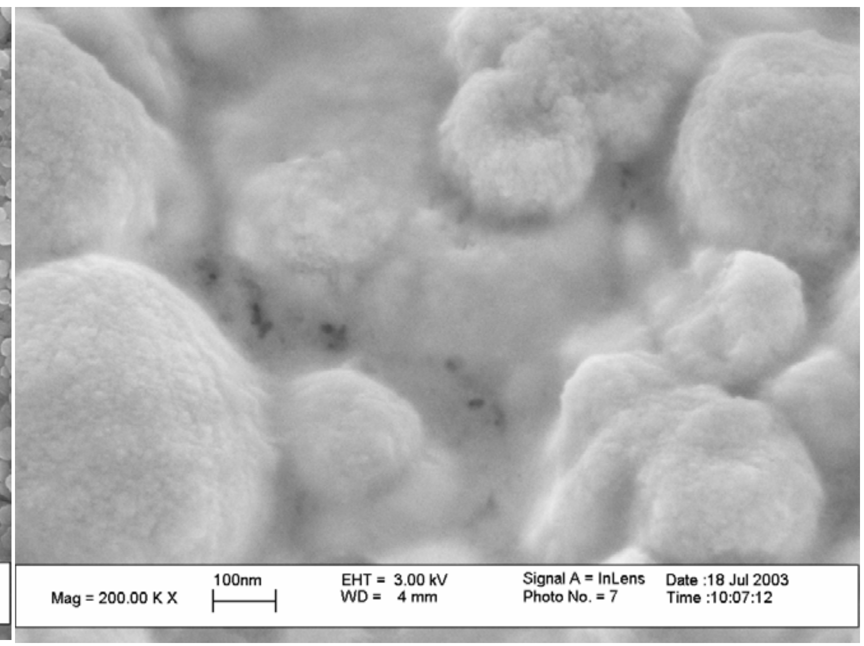
- HA raffinates contain;
  - Fission products (e.g. Sr, Mo, Zr, Cs, Ba, lanthanides).
  - Actinides (Np, Am, Cm), including low levels of U & Pu.
  - Plant corrosion products (Fe, Cr, Ni).
  - Other fuel & process additives (e.g. Gd, Mg, Al).
  - Acidic (Nitric Acid)
  - It is also heat producing (~4 watts / litre) and has an activity of ~17 TBq / litre

- During the concentration process these give several precipitates;
  - Zr phosphates.
  - Barium/strontium nitrate.
  - Cs phosphomolybdate.
  - Lanthanide nitrates or Mg lanthanide nitrates.

Cs phosphomolybdate (CPM) issues

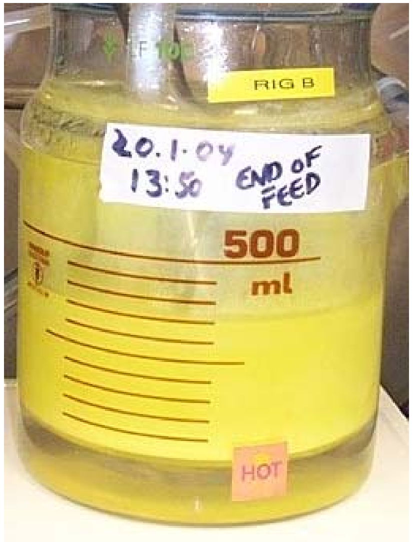
- Fast settling (*ca.* 4 g/cm^3).
- Contains radioactive isotope ^{137}Cs, *ca*. 50% of Cs.
- Formed during evaporation, but converts to zirconium molybdate which is slow settling but does not contain ^{137}Cs





Formation of CPM -HA simulant evaporation

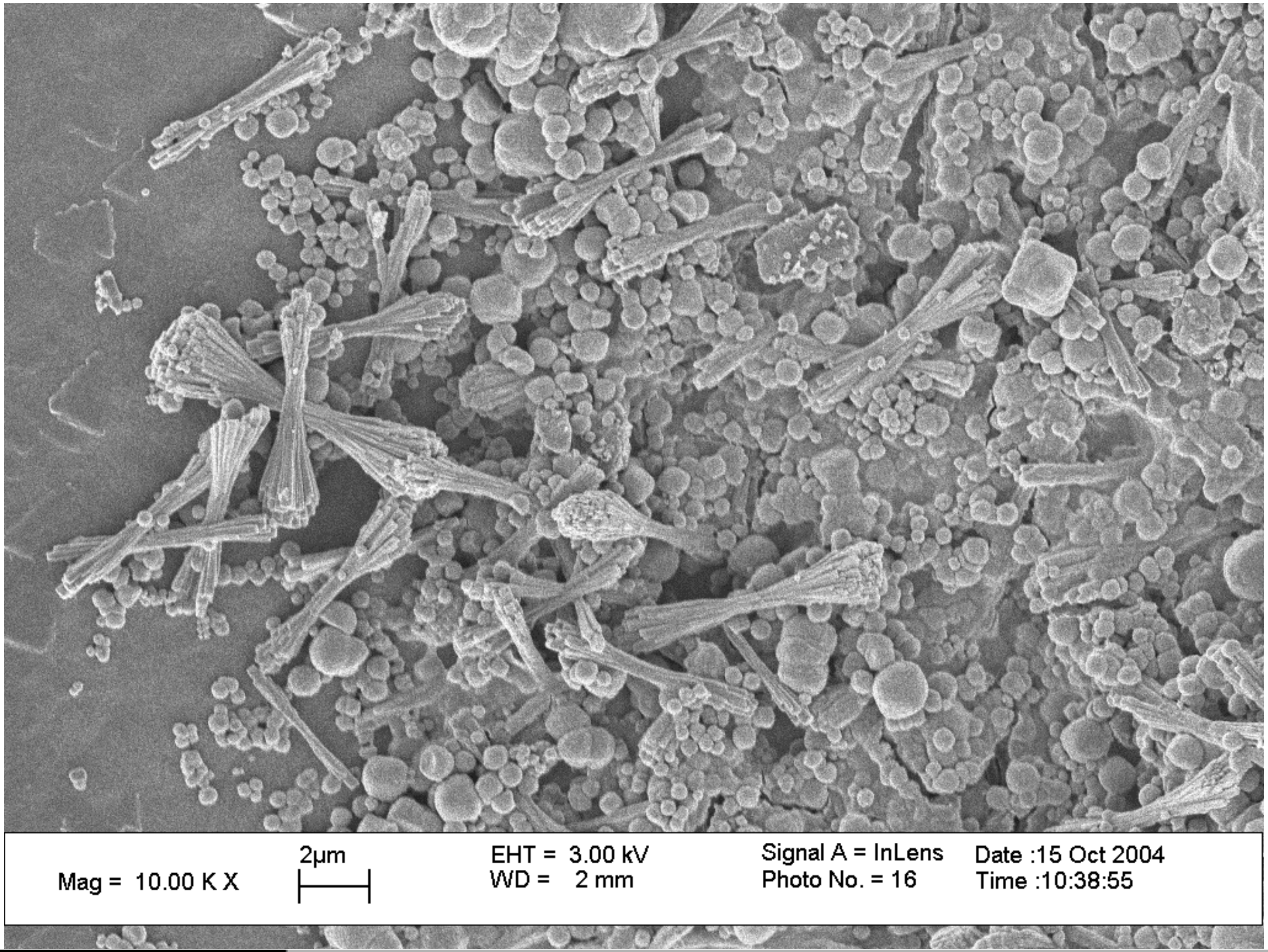
Day 1



Day 7 end feed

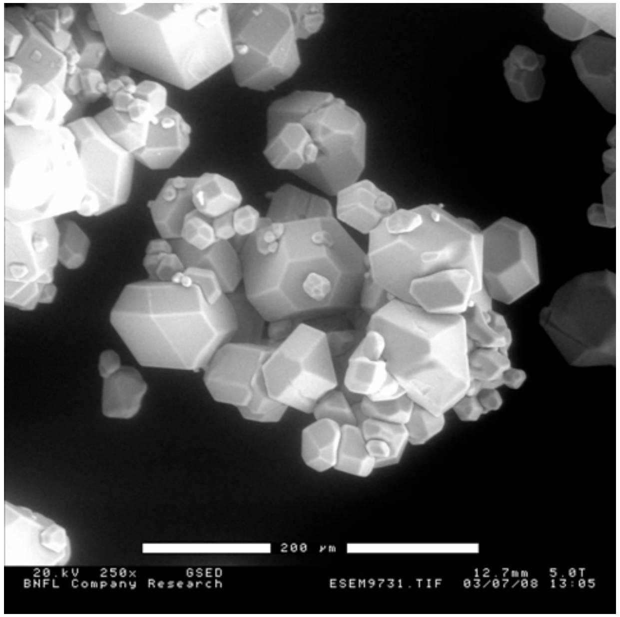
Day 20

An example of ageing Highly Active Liquor



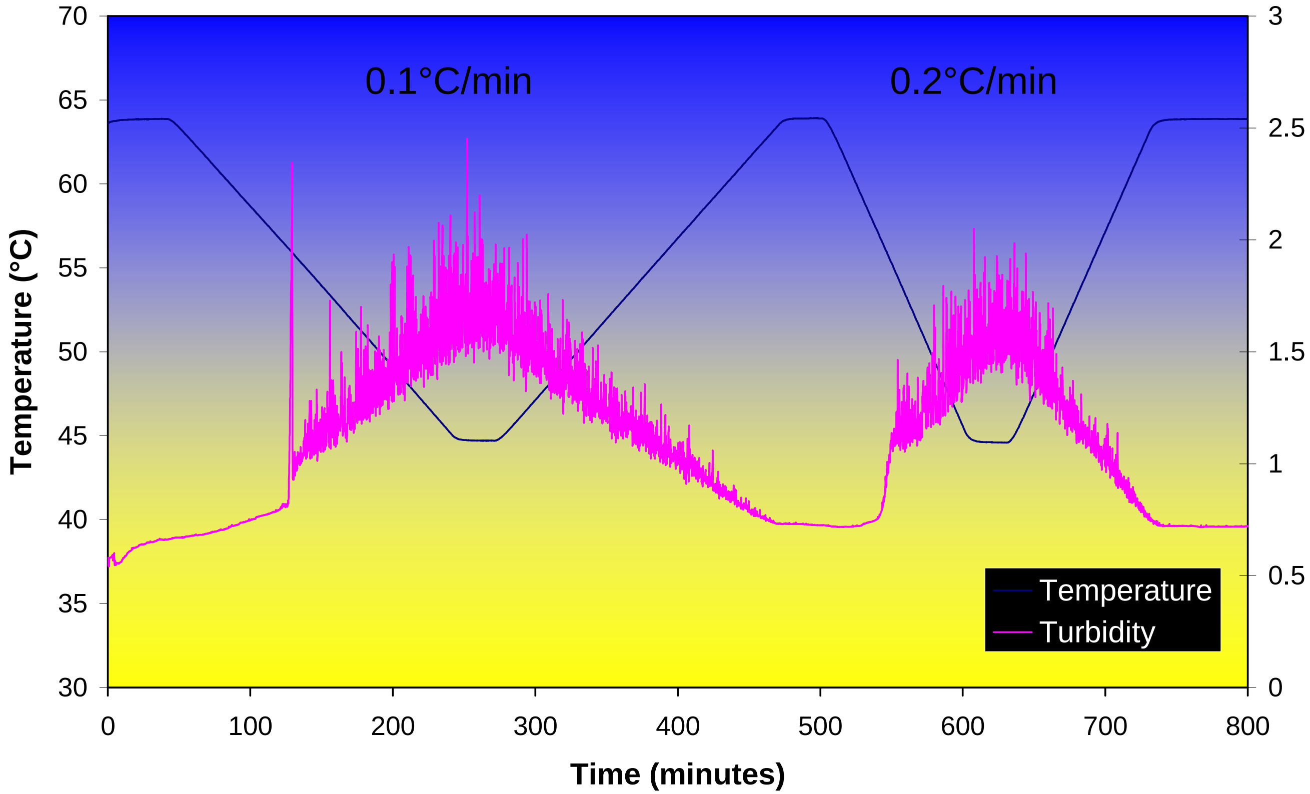
Barium/strontium nitrate issues

- Crystalline material formed during evaporation
- Acidity and temperature sensitive in the range used for storage
- Hence changes in these conditions can lead to formation of solids e.g. cold surfaces, addition of other liquors
- Can block pipes when transferred
- Noticeable meta stable zone width



Barium/strontium nitrate - Meta-stable zone widths

Whilst the precipitation occurred at the same temperature, irrelevant of cooling rate, and within 1°C of the solubility limit , there was a noticeable hindrance to dissolution.



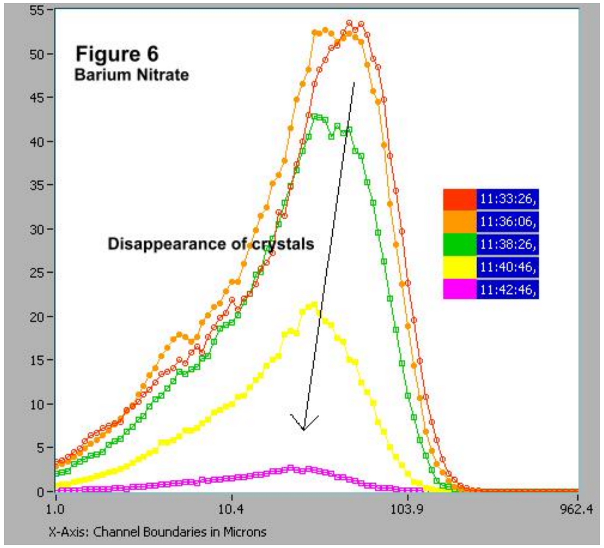
Meta-stable zone widths for 1:1 barium:strontium nitrate (solution) at two heating/cooling rates.

Characterisation of solids

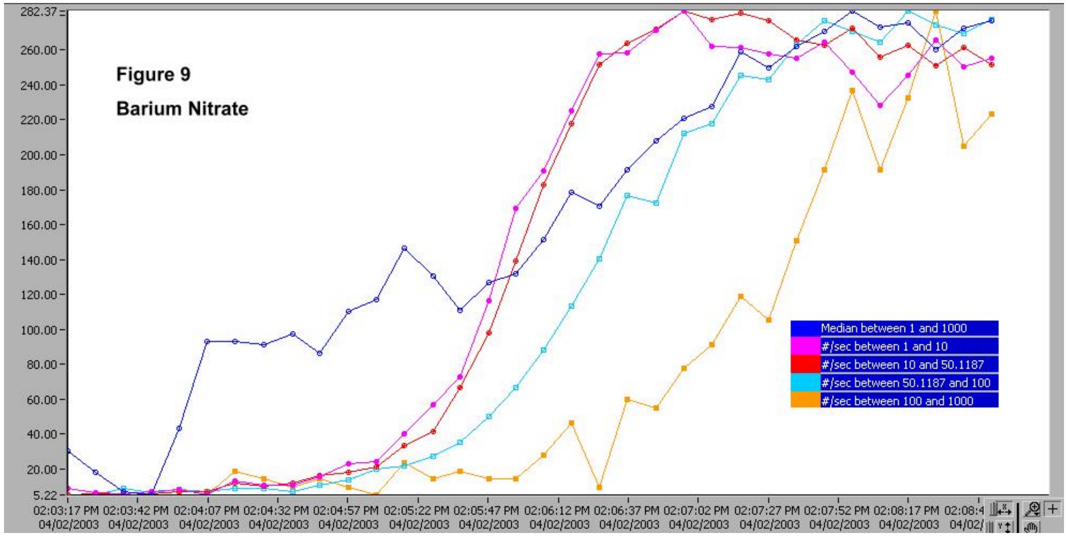
- In situ typically very difficult, but not impossible
- HAL samples limited to 3-5ml
- Use simulants, where inactive isotopes are used following a simulated process to real plant
- Chemical modelling to determine sensitivities

Particle sizes – In situ with simulants

- Particle sizing in situ using a Lasentec probe

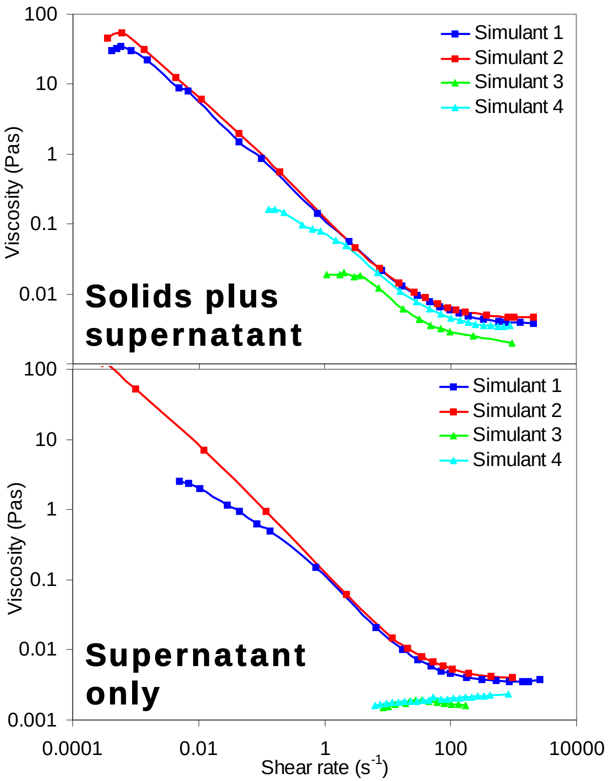


Particle sizes during the dissolution (warming) of a barium nitrate / nitric acid solution. The mean particle size is 71µm

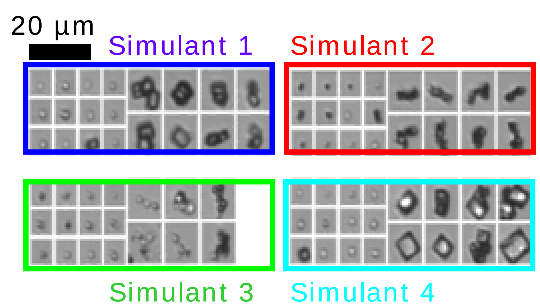


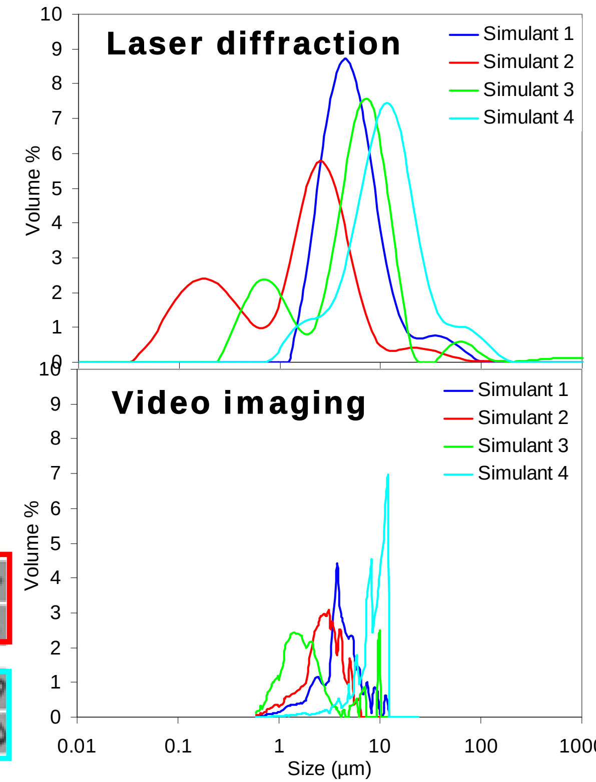
Particle sizes towards the end of a precipitation - there is a significant increase in particle count, especially in the fine region. There is also an increase in coarse particle count towards the concluding period.

Typical characterisation of simulant suspended solids



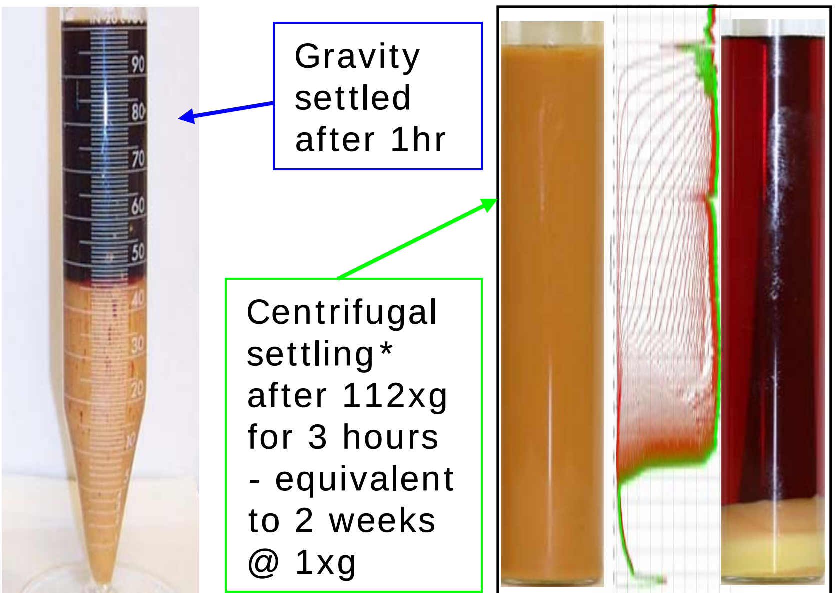
- Rheology Flow Curves
- Elemental Analysis, XRD
- Particle and Solution Density
- Solids Concentration
- Particle Size and Shape



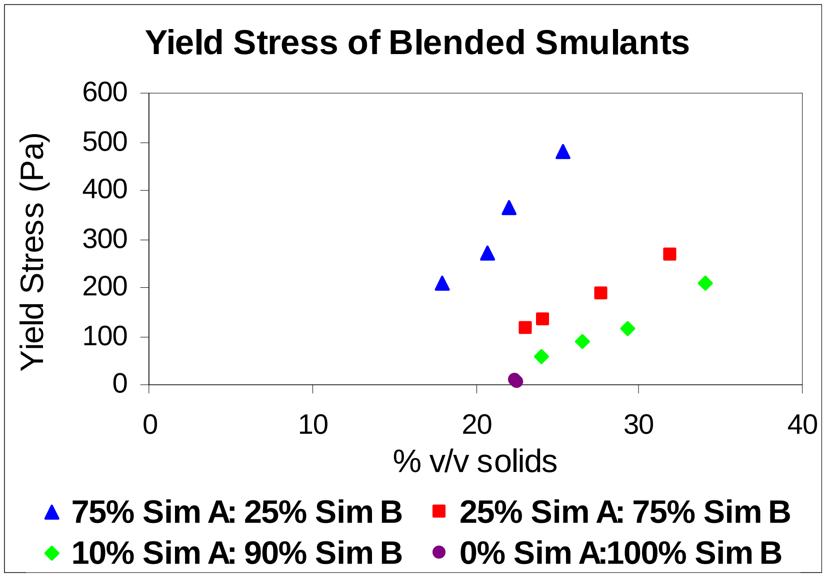


Inactive Simulant Characterisation

- Settling and sedimentation behaviour



- Shear yield stress at potential settled bed conditions

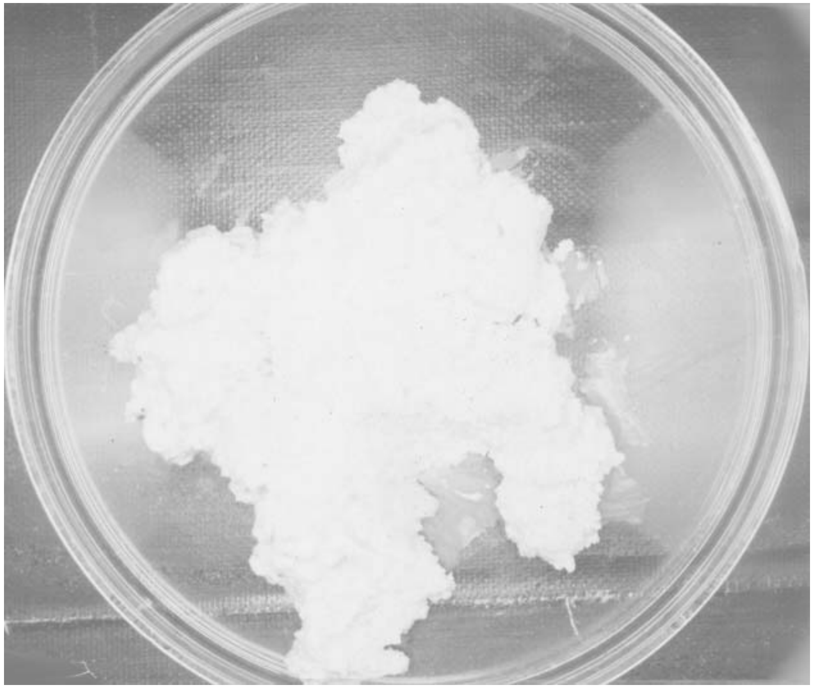


*using LUMiFuge 116 Stability Analyser

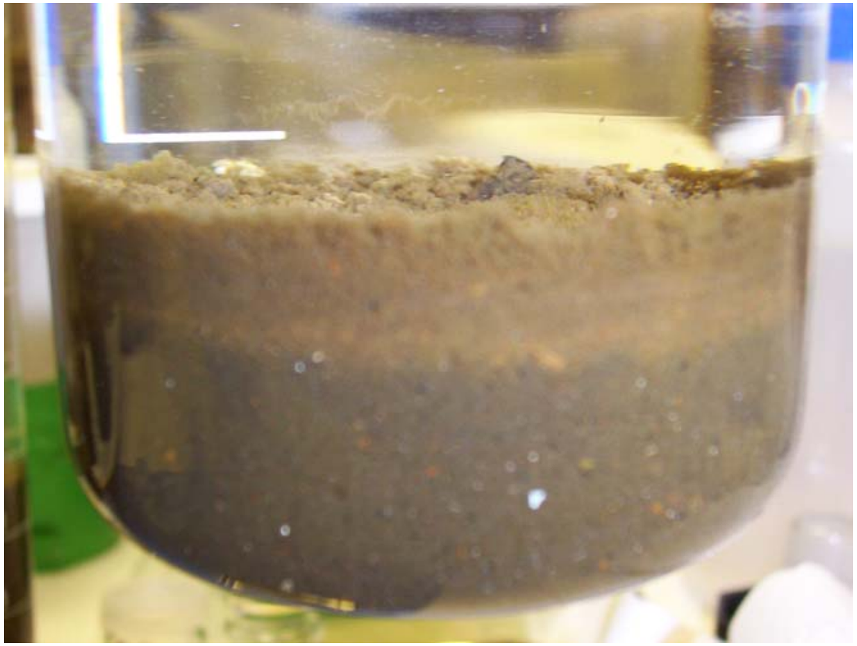
Retrieval & Treatment of Legacy Wastes

- Retrieval of legacy wastes and conversion to forms for safe storage
  - Largely cladding wastes (Mg / Al) and residual fuels
  - In ponds and silos
- Challenges
  - Characterising the waste
  - Hydrogen
  - Potential for reactive materials
  - Liquid and aerial discharges

Examples of sludges (1)

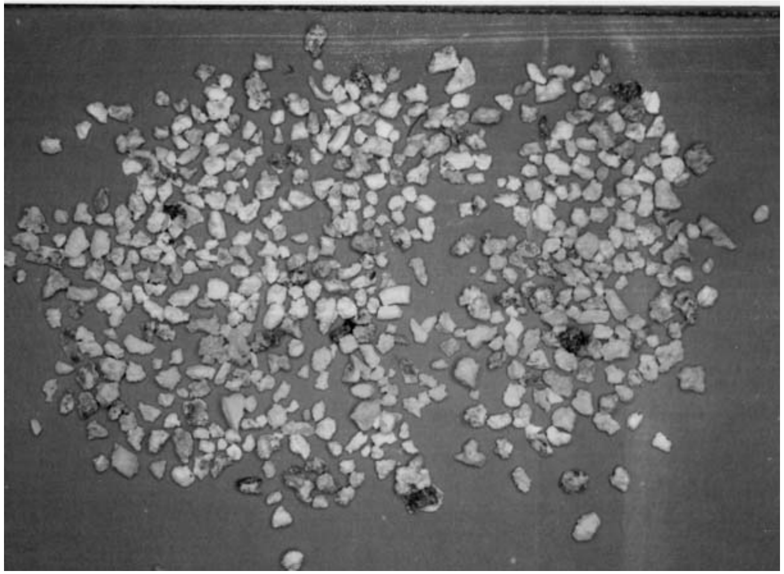


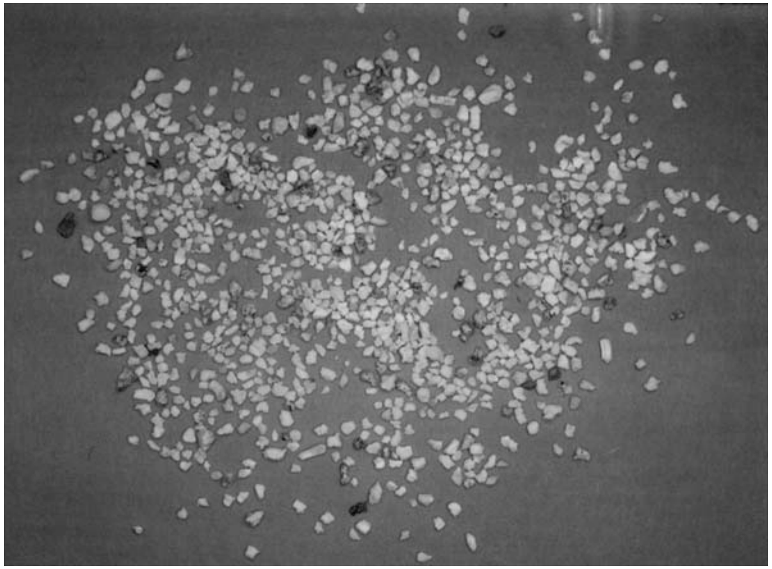
Examples of Sludges (2)



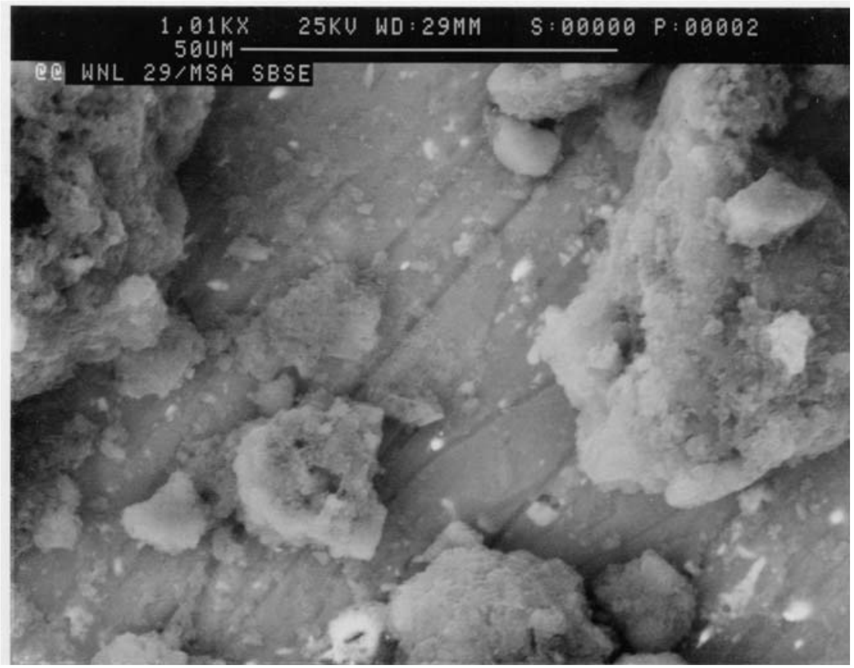
Components of sludges

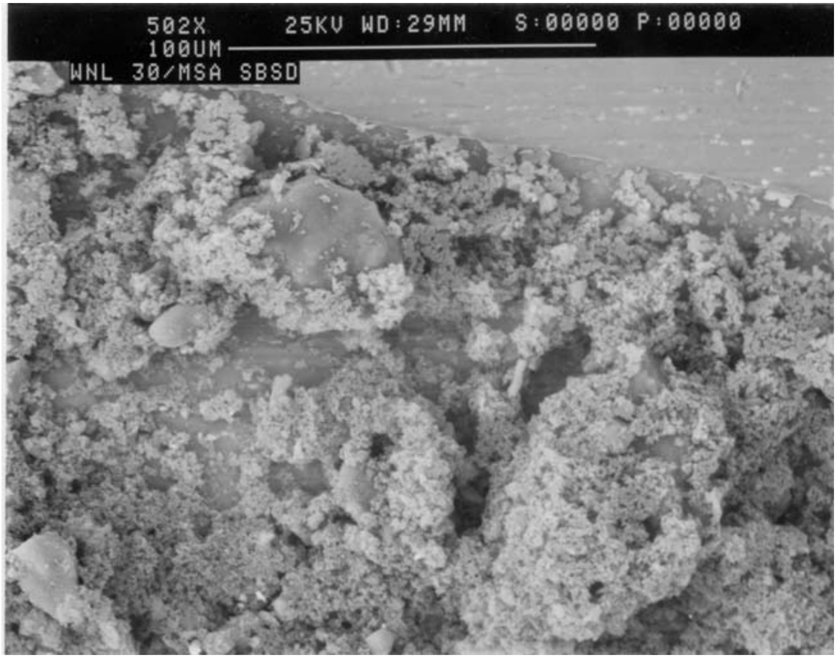
Sludge components getting smaller





Sludge components (very small)





Sludge properties

Test Materials

In-situ Experiments eg. Bell Jar

Developed to assess the amount of activity transferred from ILW sludge to the bulk liquor phase upon sludge disturbance.

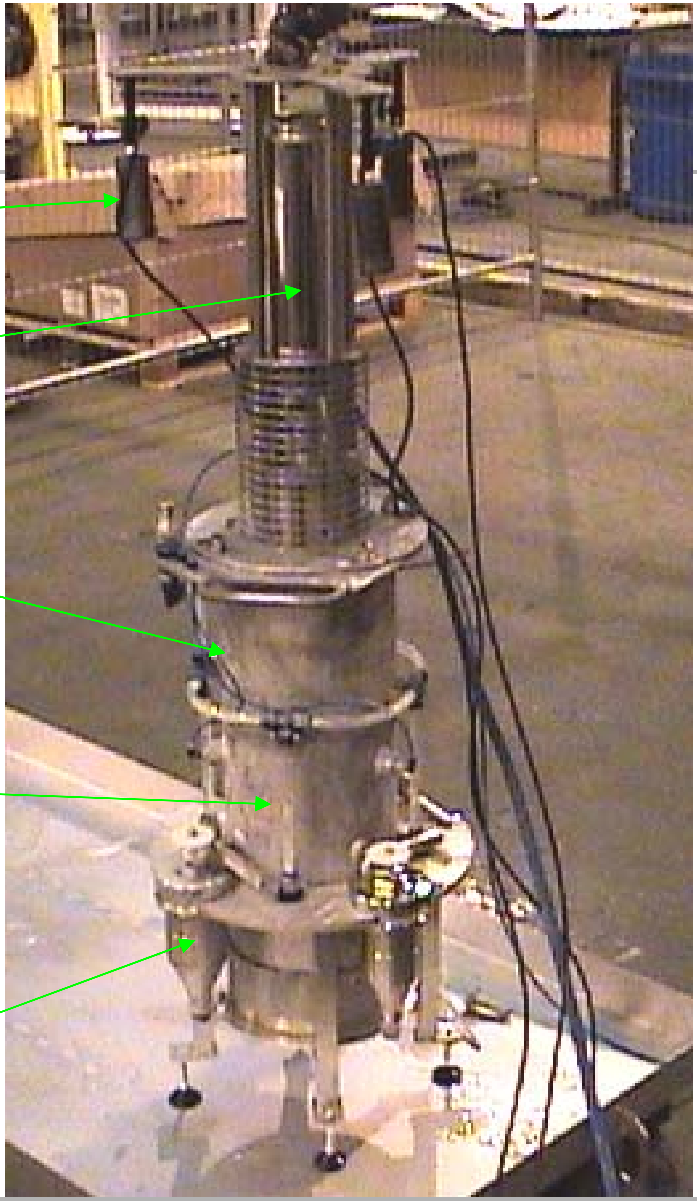
Camera

Motor

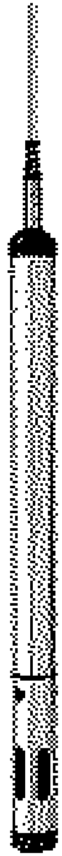
Liquor sample tube

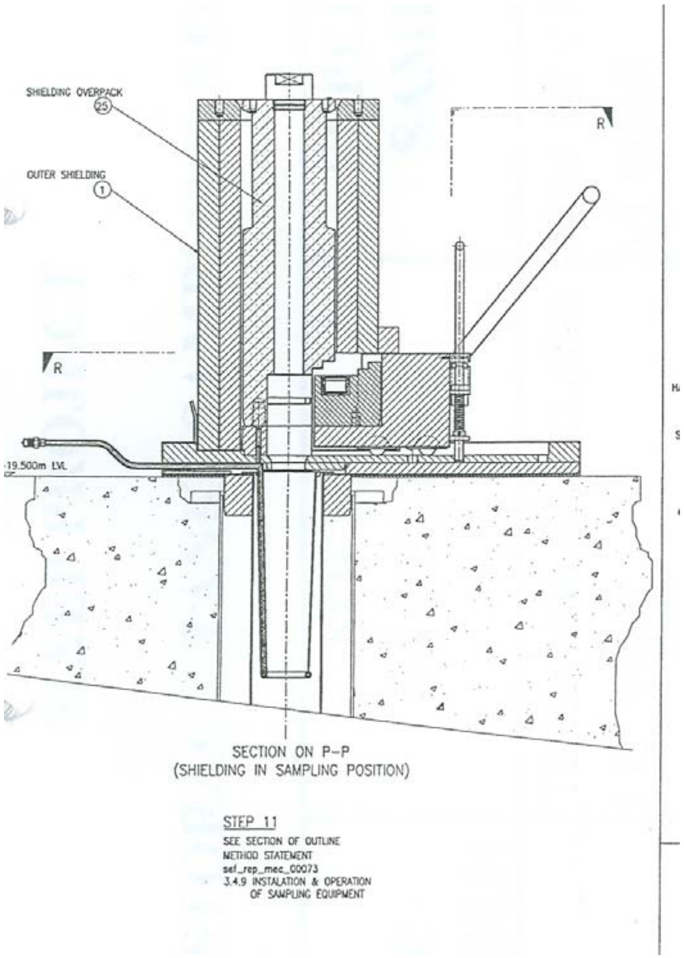
Mixing chamber

Sludge Sampler

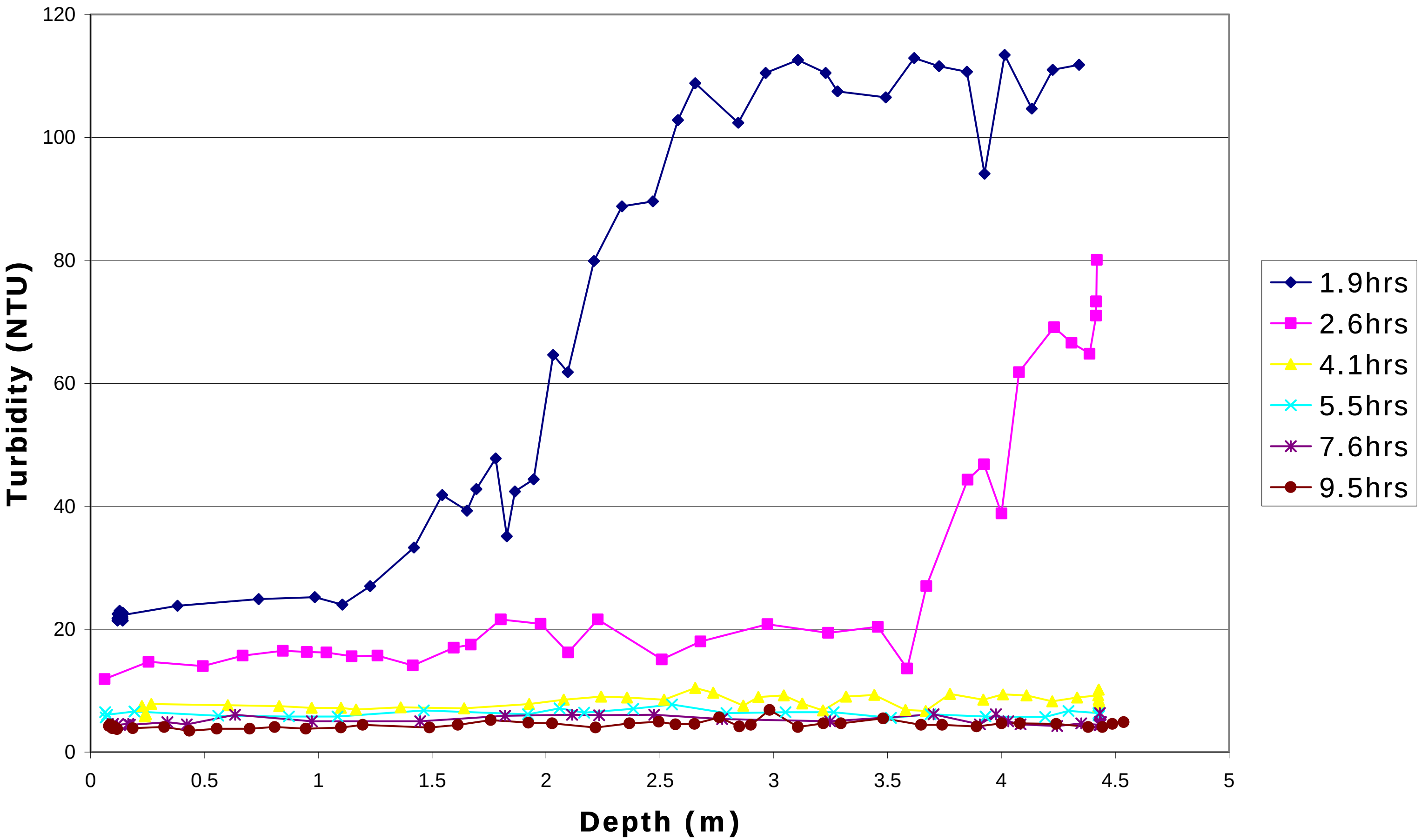


In Situ Measurements
Troll 9000





Turbidity Profile from Troll 9000



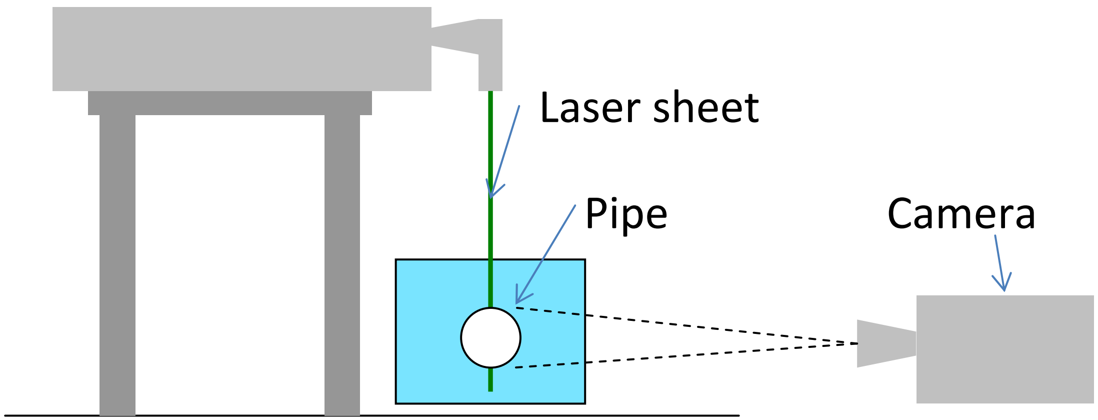
Active Sludge Sampling

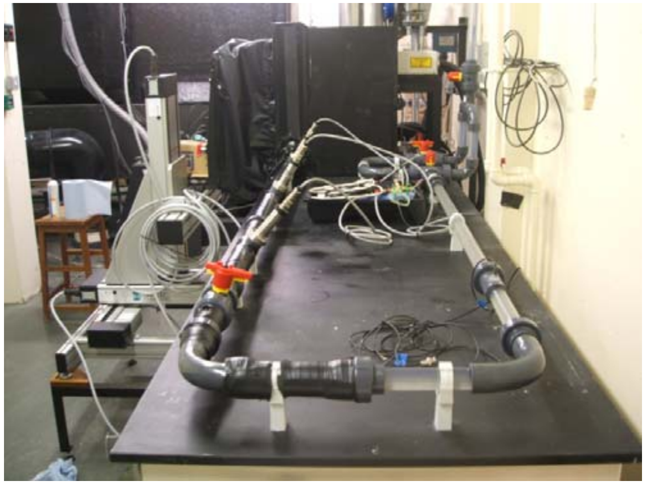
Three men fishing

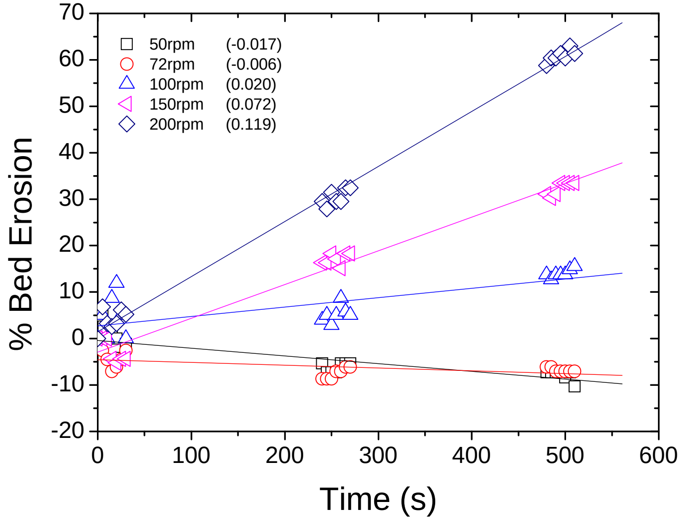
In situ Rheology

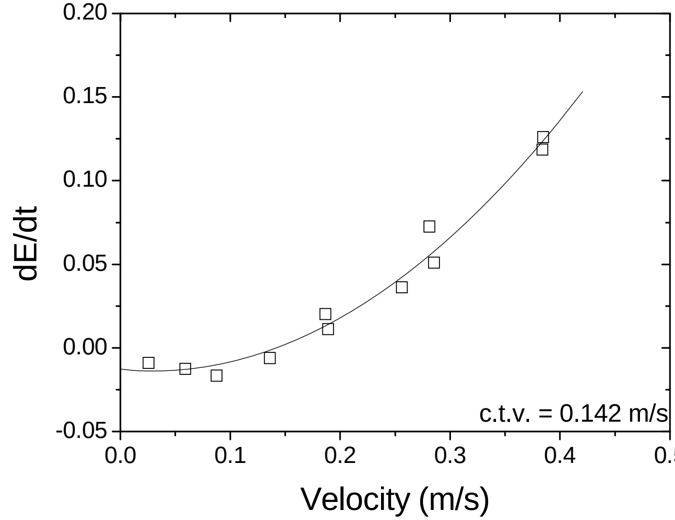
- Developing instrumentation to measure the rheological properties of slurries and pastes *in-situ* and continuously
- Application in a wide variety of industrial sectors including Nuclear
- Instrument characteristics:
  - Few mechanical parts
  - Low Cost
  - Portable
  - Compact design
  - Ease of operation

Sediment bed height as a function of time (Bed erosion) measured to determine the critical transport velocity. I.e. When bed erosion / time = 0. Image sequences where collected using a Particle Imaging Velocimetry (PIV) set-up.









Management of solids

- Closely controlled process conditions
- Defined operating enveloped based on experience and lab work
- Techniques developed to deal with issues
  - Chemical dissolution
  - Invasive – High pressure jetting, low pressure washing deployment, pigs & rods, ultrasonics, etc
  - Computer modeling

Summary

- Overview of Plant and Processes
- Examples of solid formation, and issues
- Examples of characterisation and management of solids

Acknowledgement

- NDA and Site Licence Companies for funding the various studies
- Technical contribution: Steve Graham, David Harbottle, Simon Biggs, Tracy Ward, Mike Quayle, Donna McKendrick, Jeremy Hastings, Graham McKay, Andy Fellerman, Steve Thomson